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NOISE EXPOSURE EVALUATION IN RADIO TERMINAL SET AN/TRC-112, 21 --ETC(U)
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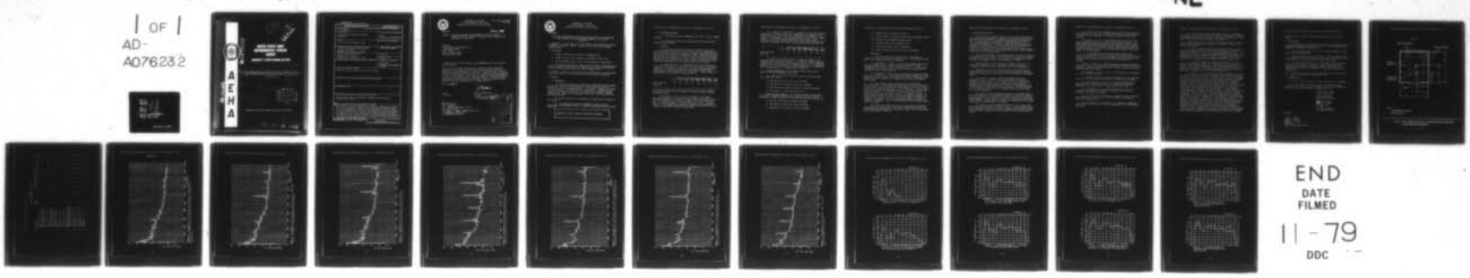

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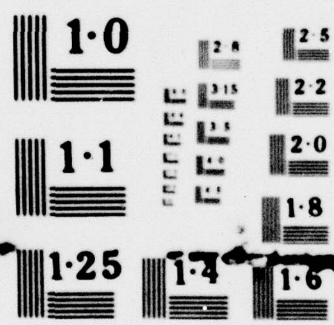
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UNITED STATES ARMY ENVIRONMENTAL HYGIENE AGENCY

ABERDEEN PROVING GROUND, MD 21010

(14) USAEHA-51-34-0223-80

(21) Report on

ACOUSTICAL ENGINEERING NOISE REDUCTION SPECIAL STUDY NO. 51-34-0223-80

(6) NOISE EXPOSURE EVALUATION IN RADIO TERMINAL SET AN/TRC-112,

21 JUNE 1979.

(12) 24

(9) Final rept.,

(11) 19 Oct 79

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(10) Felip Z. Sachs
Jeffery D. New

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Noise levels in two radio terminal sets, AN/TRC-112, were measured to determine if the operators are exposed to noise hazardous levels and to define noise control approaches if required. The noise levels in the two terminal sets were below the US Army 85 dB, A-weighted hearing conservation criterion. The character of the noise was judged to be annoying because of an audible high frequency whine. Some noise control is relatively easily attainable but reductions of more than about 4 dB and elimination of the whine will require some redesign of the power amplifier.

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DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010

Mr. Sachs/cw/AUTOVON
584-3797

HSE-OB/WP

19 OCT 1979

SUBJECT: Acoustical Engineering Noise Reduction Special Study No. 51-34-0223-80, Noise Exposure Evaluation in Radio Terminal Set AN/TRC-112, 21 June 1979

Commander
US Army Materiel Development and
Readiness Command
ATTN: DRCSG
5001 Eisenhower Avenue
Alexandria, VA 22333

A summary of the pertinent findings and recommendations of the inclosed report follows:

Noise levels in two radio terminal sets, AN/TRC-112, were measured to determine if the operators are exposed to noise hazardous levels and to define noise control approaches if required. The noise levels in the two terminal sets were below the US Army 85 dB, A-weighted hearing conservation criterion. The character of the noise was judged to be annoying because of an audible high frequency whine. Some noise control is relatively easily attainable but reductions of more than about 4 dB and elimination of the whine will require some redesign of the power amplifier.

FOR THE COMMANDER:

J. W. Thiessen

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COL, MC
Director, Occupational and
Environmental Health

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as (10 cy)

CF:
HQDA (DASG-PSP)
Cdr, HSC (HSPA-P)
Cdr, USAMSAA (DRXSY-LM/Mr. Forst)
Supt, AHS (HSA-IPM)
Cdr, MEDDAC, Ft Meade (PVNTMED Actv)(2 cy)
C, Delaware National Guard
C, USAEHA Rgn Div-North

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ACOUSTICAL ENGINEERING NOISE REDUCTION SPECIAL STUDY NO. 51-34-0223-80 NOISE EXPOSURE EVALUATION IN RADIO TERMINAL SET AN/TRC-112 21 JUNE 1979

1. AUTHORITY. Letter, DRXSY-LM, US Army Materiel Systems Analysis Activity (USAMSAA), 17 May 1979, subject: Request for Services of Environmental Hygiene Agency.

2. REFERENCES.

a. AR 40-5, Health and Environment, 25 September 1974.

b. TB MED 251, Noise and Conservation of Hearing, 7 March 1972.

c. MIL-STD-1474A(MI), Noise Limits for Army Materiel, 3 March 1975.

d. TDC 70-54, Engineering Test Report on Acoustical Noise Performance of Radio Set AN/GRC-143 (and Radio Set AN/GRC-144), ITT Defense Communications Division, 492 River Road, Nutley, NJ 07110, December 1970.

3. PURPOSE. To assess the noise conditions associated with two troposcatter radio sets, AN/TRC-112, and define appropriate noise control measures.

4. GENERAL.

a. Background.

(1) The radio terminal set, AN/TRC-112 (tropospheric scatter system) consists of a shelter (74-inches wide by 79-inches long) containing an AN/GRC-143 radio set and other equipment. The shelter is mounted on the back of a 3/4-ton truck. The AN/TRC-112 is a signal carrier. Messages are not received, transmitted, or monitored by the AN/TRC-112 personnel. However, audible alarms, which indicate equipment malfunctions, are monitored by the AN/TRC-112 personnel.

(2) Several operators of the AN/TRC-112's complained of the noise in the shelters.

(3) This Agency was requested by USAMSAA to assess the noise conditions in the two AN/TRC-112 sets, located at the Delaware National Guard facilities.

b. Personnel Contacted.

(1) The point of contact at USAMSAA was Mr. Harold C. Forst, AUTOVON 283-4473.

(2) The point of contact at the Delaware National Guard was WO T. Logeman, AUTOVON 455-9320.

c. Criteria.

(1) The hearing conservation criteria for US Army military and civilian personnel are specified in AR 40-5 which defines a hazardous noise level as any steady noise level exceeding 85 decibels, A-weighted [dB(A)] or any impulse noise exceeding 140 peak decibels (dBP). AR 40-5 requires that hearing conservation measures per TB MED 251 be initiated whenever personnel are exposed to such hazardous noise levels. Among the hearing conservation measures required is the elimination, when feasible, of the hazardous noise levels by the implementation of engineering noise control measures.

(2) Design standards for noise generated by US Army materiel are listed in MIL-STD-1474. The design limits for steady noise are categorized according to the intended use, generally according to speech communication requirements. Category D is applicable to areas where frequent direct person-to-person voice communication is not required. To meet Category D no octave band level may exceed the following limits:

	Octave Band Center Frequency, Hertz (Hz)							
	63	125	250	500	1000	2000	4000	8000
Octave band noise level, dB	106	96	89	83	80	79	79	81

The limits of Category D are generally equivalent to the Army's 85 dB(A) hearing conservation criterion, although it is possible to meet Category D and exceed 85 dB(A).

(3) Category E of MIL-STD-1474 is applicable to areas where occasional telephone use or occasional direct communication at distances up to 5 feet are required. The limit for Category E is a noise level of 75 dB(A) or a preferred speech interference level (PSIL-4) of 67. The PSIL-4 level is a widely used measure of the effectiveness of noise in masking speech. It is determined by arithmetically averaging the octave band levels in the 500, 1000, 2000, and 4000 Hz octave bands.

(4) Category F of MIL-STD-1474 is applicable to areas where frequent telephone use or frequent direct voice communication at distances up to 5 feet are required. The noise limits for Category F are 65 dB(A) or a PSIL-4 level of 57. Category F is also intended to be equivalent to NC-60. The NC series of noise criteria was developed in 1957 and is widely used in commercial practice by architects and others in specifying the design limits for noise in buildings of all kinds. The octave band levels for NC-60 are:

	Octave band center frequency, Hz							
	63	125	250	500	1000	2000	4000	8000
Octave band noise level, dB	77	71	67	63	61	59	58	57

(5) There are no US Army criteria for noise with respect to its annoyance effects on equipment operators. In commercial practice, there are annoyance rating schemes for noise but these are usually used for comparison purposes and not for making absolute annoyance predictions. It is generally recognized that a noise containing an audible discrete tone is more annoying than a noise composed only of random pressure fluctuations.

d. Field Instrumentation. The following instruments were used at Newport to acquire the AN/TRC-112 noise data.

(1) Bruel and Kjaer (B&K) model 2209 precision sound level meter, serial number (SN) 477388.

(2) B&K model 1613 octave filter set, SN 310241.

(3) B&K model 4220 pistonphone calibrator, SN 306350.

(4) B&K model 4134 condenser microphones, SN 431156 and 456393.

(5) Nagra model IV SJ tape recorder, SN 7124.

e. Laboratory Instrumentation. The following instruments were used at the US Army Environmental Hygiene Agency (USAEHA) Bio-Acoustics Division laboratory to analyze the AN/TRC-112 noise data tape recorded at Newport, DE.

(1) B&K model 2130 frequency analyzer, SN 473384.

(2) B&K model 4710 control and display, SN 476009.

(3) B&K model 1616 1/3-octave filter set, SN 579239.

(4) Raytheon model 704 computer, SN 13700.

(5) Spectral Dynamics (SD) model SD 301C real-time analyzer, SN 202.

(6) SD model SD 302C ensemble averager, SN 198.

(7) SD model SD 305A octave converter, SN 49.

(8) Houston model 2000 recorder, SN R4826-300.

(9) Tektronix model DC 503 univeral counter, SN B153605.

f. Procedures.

(1) Noise measurements were made primarily to determine if AN/TRC-112 operators are exposed to hazardous noise. Some measurements were made to aid in defining noise control measures.

(2) Measurements in support of noise hazard assessment were made at the two microphone positions shown on the Figure, Appendix A. Both microphone positions were at the approximate ear level of a seated operator. The operator can be at any location inside the shelter, but position 2 is reportedly his most probable location.

(3) Octave band filtered noise level readings were taken during the onsite visit at Newport, DE. These data are tabulated in Appendix B. Noise data were also tape recorded and the tapes were subsequently analyzed at the USAEHA Bio-Acoustics laboratory. Narrowband and 1/3-octave band analyses were performed.

(4) The narrowband analyses were performed using the SD301C real-time analyzer. The frequency ranges were set at 10,000 Hz or 20,000 Hz. In the 10,000 Hz setting the effective filter bandwidth is 30 Hz, the filter spacing is 20 Hz, and the sample period is 50 milliseconds. In the 20,000 Hz setting the effective filter bandwidth is 60 Hz, the spacing is 40 Hz, and the sample period is 25 milliseconds. The statistical quality of the analysis of one sample period is equivalent to two degrees of freedom. The SD302C ensemble averager was used to average the narrowband analyses of 64 sample periods to yield a statistical quality equivalent to 128 degrees of freedom for the ensemble. Plots for the averaged narrowband analyses are presented in Appendix C. Each plot represents the analysis of a total sample time of 3.2 seconds.

(5) The 1/3-octave band analyses of the taped data were performed using the B&K real-time analyzer. The output of the analyzer was fed into the Raytheon 704 computer for hard copy graphic display. The 1/3-octave band plots are presented in Appendix D.

5. FINDINGS AND DISCUSSION.

a. The noise level at operator positions in the two radio terminal sets during normal operation was 80 to 83 dB(A). With the power amplifier (PA) doors open, the noise level was 82 and 85 dB(A) depending on the terminal set. The above levels do not exceed the US Army hearing conservation criterion and therefore, the conditions in these two terminal sets are not considered noise hazardous. It should be noted that the US Army hearing conservation criterion is based on an 8 hour-per-day work shift. If operators of the terminal set are routinely exposed to these types of noise levels for 16 hours-per-day during peacetime then any noise level 81 dB(A) or higher would be considered hazardous.

b. The octave band noise levels (Appendix B) generally meet the criteria for Category D of MIL-STD-1474. The only exception is in one of the terminal sets where the noise in the 4000 Hz octave band is 82 dB when the PA doors are open. The Category D limit in this octave band is 79 dB.

c. The noise levels in the shelters are in excess of the limits for MIL-STD-1474 Categories E and F. The shelters therefore, cannot be considered suitable for reliable telephone or direct voice communication.

d. Subjectively, the noise inside the shelters is characterized by a high-pitched whine riding on top of a broad band random noise. The broad band noise is generated by the equipment ventilation fans and by the shelter blowers.

(1) Figure C1, Appendix C shows the narrowband spectrum at microphone position 1 in terminal set T-07-015-02 (set -02) during the terminal set turnon sequence. At this phase of the turnon sequence, the equipment ventilation fans and shelter blowers were on but the radio frequency (RF) output power was less than 1 watt. The narrowband spectrum has an essentially smooth profile with only one small (6 dB) spike at 2850 Hz. This spectrum is indicative of a broadband random noise with a very small pure tone component.

(2) Figure C2 is the narrowband spectrum of a noise sample taken a short time interval after the sample which yielded the spectrum in Figure C1. The only difference in the operational conditions is that full RF power was being generated. Figure C2 shows a 15 dB spike at about 6100 Hz and an 8 dB spike at 9100 Hz. These spikes are the spectral representations of the whine audible when the inverter power is increased.

(3) Figure C3 is the narrowband spectrum of a noise sample taken a few minutes after the samples of Figures C1 and C2. Figure C3 shows a shift in the frequencies of the first two spikes, from 2850 Hz to 3250 Hz and from 6100 Hz to 6500 Hz respectively, and the presence of an additional spike at 9750 Hz.

(4) Figure C4 is the narrowband spectrum of the noise a short time after the sample for Figure C3. Figure C4 was generated with the analyzer in the 20,000 Hz setting and shows the presence of spikes at 12,300 Hz and 15,800 Hz.

(5) Figures C5, C6 and C7 are narrowband spectra for three noise samples recorded at position 2 in terminal set T-07-015-07 (set-07). All three samples were tape recorded when the set was generating full RF power, PA doors were open and the equipment fans were vented outside the shelter. The analyzer was set at 10,000 Hz for Figures C5 and C6 and at 20,000 Hz for Figure C7. The shelter door was open wide during the sample for Figure C6; closed for all other samples.

(6) The narrowband spectra show that the whine heard in the shelters is a complex tone consisting of several pure tone components in the audible frequency range. The pure-tone components are present only when the RF power is up. The tones vary with time, both in magnitude and in frequency.

e. Appendix D shows the 1/3-octave band analysis for several operating conditions. The 1/3-octave band spectra show some variation, particularly at the higher frequencies, even when there was no change in operating conditions between analyzed noise samples.

f. The narrowband, 1/3 octave, octave, and A-weighted data in Appendices B, C, and D show the following:

(1) Opening the PA doors raises the A-weighted noise in the shelter by about 2 dB. This is the case for both full RF power and no RF power.

(2) The A-weighted noise level is not measurably affected by RF power generation. The whine produced by the inverter during RF power generation is audible but does not raise the overall noise level.

(3) The difference in noise levels between sets -02 and -07 is caused by the difference in the blower and fan noise and not by the difference in the level of the whine.

(4) The noise level in the shelter is reduced by about 2 dB when the shelter blowers are turned off and all other equipment and equipment ventilation fans are left on.

(5) The noise level in the shelter is not measurably changed when the PA exhaust is switched from outside (summer operation) to inside (winter operation).

(6) In terms of the overall A-weighted noise level in the shelter, the dominant source is the PA ventilation system, the next greatest source is the shelter exhaust system (two blowers), and the third ranked source is the whine produced by the inverter during RF power generation.

g. Some noise reduction is fairly easily attainable; however, since the dominant source is the PA cooling system, any significant noise reduction requires some redesign.

(1) The most easily attainable noise reduction method is addition of acoustically absorptive material to the shelter surfaces. At present, the shelter walls and ceiling are lined with painted sheetmetal which is acoustically reflective in the mid and upper audible frequency ranges. These reflective walls cause a reverberant buildup of the noise in the shelter. Approximately 20 ft^2 of 1-inch thick acoustical foam were placed in set -07, resulting in a 2 dB reduction in the overall noise level at position 2.

(2) The shelter blowers are mounted on the forward wall of the shelter and appear easily accessible. Small mufflers, consisting of a short section of duct lined with about 2-inch thick acoustically absorptive material, can be placed on the blower intakes. This would yield some noise reduction. More than 1 or 2 dB cannot be expected since the noise level in the shelter is reduced by only 2 dB when the blowers are off.

(3) Reduction of the audible whine requires some redesign of the PA. The source of the whine is a magnetic component of the inverter within the PA. For this type of component, the following mechanism of noise generation and propagation would be expected: the AC current in the magnetic component causes oscillating forces which vibrate the component and its support structure. The vibration propagates through the chassis to the external surfaces of the PA. These surfaces then radiate noise into the shelter. The radiated noise can be reduced by either reducing the oscillating forces at their source or by interrupting the propagation path. One method of interrupting the path would be to install vibration isolators somewhere between the magnetic component and the PA surfaces. A vibration isolator was jury-rigged. Strips of acoustical foam were placed between the inverter assembly and its support chassis. Noise levels measured at 22 inches from the inverter are listed as items 12 and 13 in Appendix B. Measurements were made for two conditions: one with the inverter bolted in place in its normal manner, and the other with the inverter on the jury-rigged vibration isolators. The octave band data show a 5 and 6 dB reduction in the 4000 and 8000 Hz bands, producing about 2 1/2 dB reduction in the A-weighted level. There was an increase in the 16,000 Hz band but this is outside the A-weighting filter. Analysis and further testing are required before a vibration isolation system should be seriously considered. Among the items requiring resolution are whether the reductions in the noise in the 4000 and 8000 Hz bands are indeed due to the isolators and not the result of normal

time variation or a change in the boundary conditions at the inverter chassis.

6. CONCLUSIONS.

a. Noise conditions in the two AN/TRC-112 terminal sets measured do not exceed the US Army hearing conservation criteria. The noise conditions are therefore not considered noise hazardous.

b. The noise levels exceed the limits for reliable telephone or direct person-to-person communications.

c. Subjectively, the noise in the shelters is annoying; however, there are no applicable criteria for annoyance in this case. A significant factor in the annoyance is the audible whine produced by the inverter.

d. Up to 4 dB of noise reduction can be relatively easily achieved by adding acoustically absorptive material in the ceiling and walls, and installing simple mufflers on the shelter blowers. Additional noise reduction and elimination of the whine require more extensive testing and some redesign.

e. There is some variation in noise level among different transmitter sets. Units louder than the two measured may exist.

7. RECOMMENDATIONS.

a. Continue using sets -02 and -07 under present operating procedures.

b. If noise levels at 85 dB(A) or higher are suspected in other transmitter sets, request a noise measurement from the Preventive Medicine Office of the cognizant Army Medical Department Activity.

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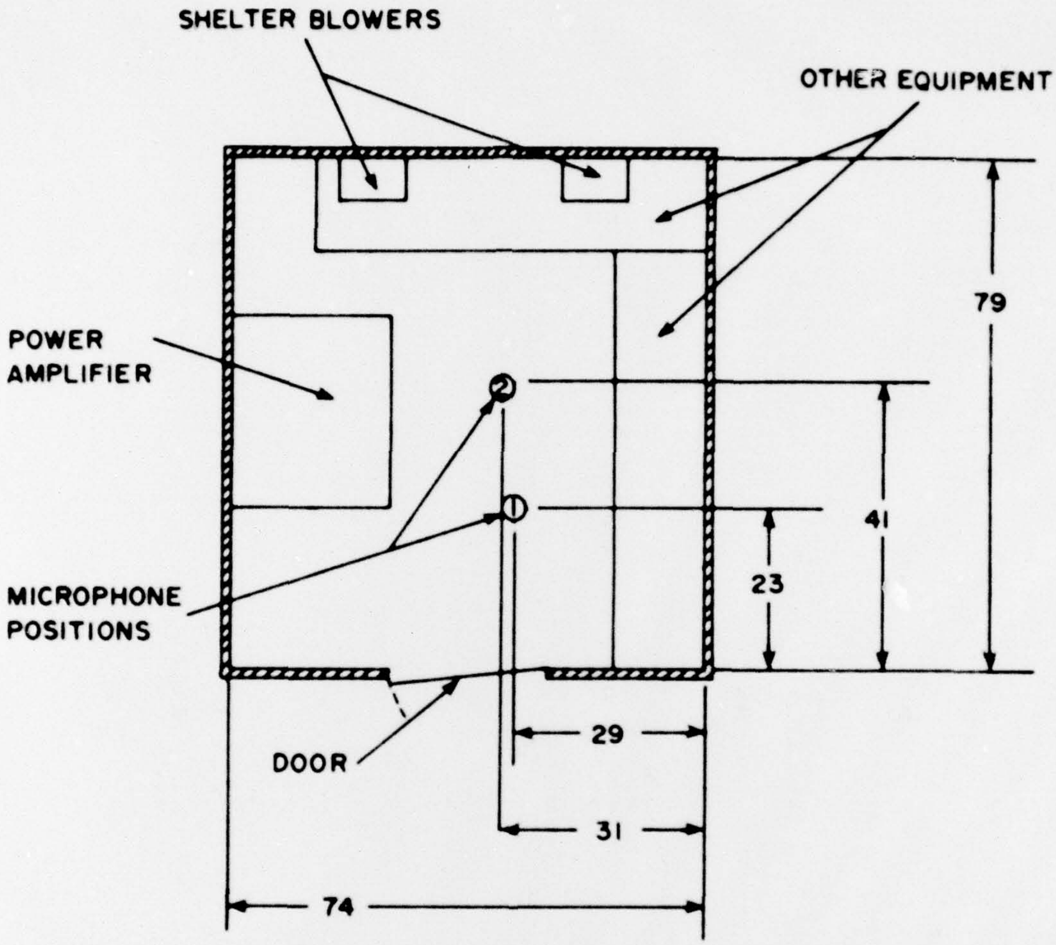
APPENDIX A



NOTE

1. DIMENSIONS IN INCHES
2. NOT TO SCALE

FIGURE. PLAN VIEW OF AN/TRC-112 SHELTER AND LOCATION OF MICROPHONE POSITIONS

APPENDIX B

OCTAVE BAND DATA MEASURED AT NEWPORT, DE

Item	Location and Condition	Noise Level dB(A)	Octave Band Center Frequency, Hz									
			31	63	125	250	500	1000	2000	4000	8000	16000
	AN/TRC-112 SN T-70-015-02											
1	Shelter blowers on, normal RF power, PA exhausted outside, PA doors open, microphone position No. 1	82	76	72	76	79	75	76	76	72	69	76
2	Same as above but PA doors closed	80	76	67	73	77	74	75	75	71	66	62
3	Same as above but at position No. 2	81	76	65	74	78	75	75	75	71	68	61
4	Shelter blowers on, no RF power, inverter off, PA exhausted outside, PA doors closed, position No. 2	81	76	66	74	78	75	75	76	71	65	58
5	Same as above but PA exhausted inside shelter (as for winter operation)	81	71	69	74	79	75	75	76	72	66	59
6	Same as above but RF power on and inverter on	81	71	69	74	79	75	75	76	72	66	59
7	Same as above but PA doors open	82	65	64	76	80	76	75	77	73	69	64
	AN/TRC-112 SN T-70-015-07											
8	Shelter blowers on, normal RF power, PA exhausted outside, PA doors open, inverter on, microphone position No. 2	85	82	71	79	81	79	76	77	82	75	70
9	Same as above but PA doors closed	83	80	71	76	80	78	75	76	74	74	66
10	Same as item 8 but acoustical foam placed in shelter	81	77	71	79	78	74	73	73	71/72	74	64
11	Same as above but shelter blowers off	79	79	68	79	74	72	71	72	74/76	72	60
12	PA doors open, microphone 22 in. from inverter	84		68	74	77	73	73	74	77	82	66
13	Same as above but inverter on foam pads	81.5		65	76	77	73	73	73	72	76	79

APPENDIX C

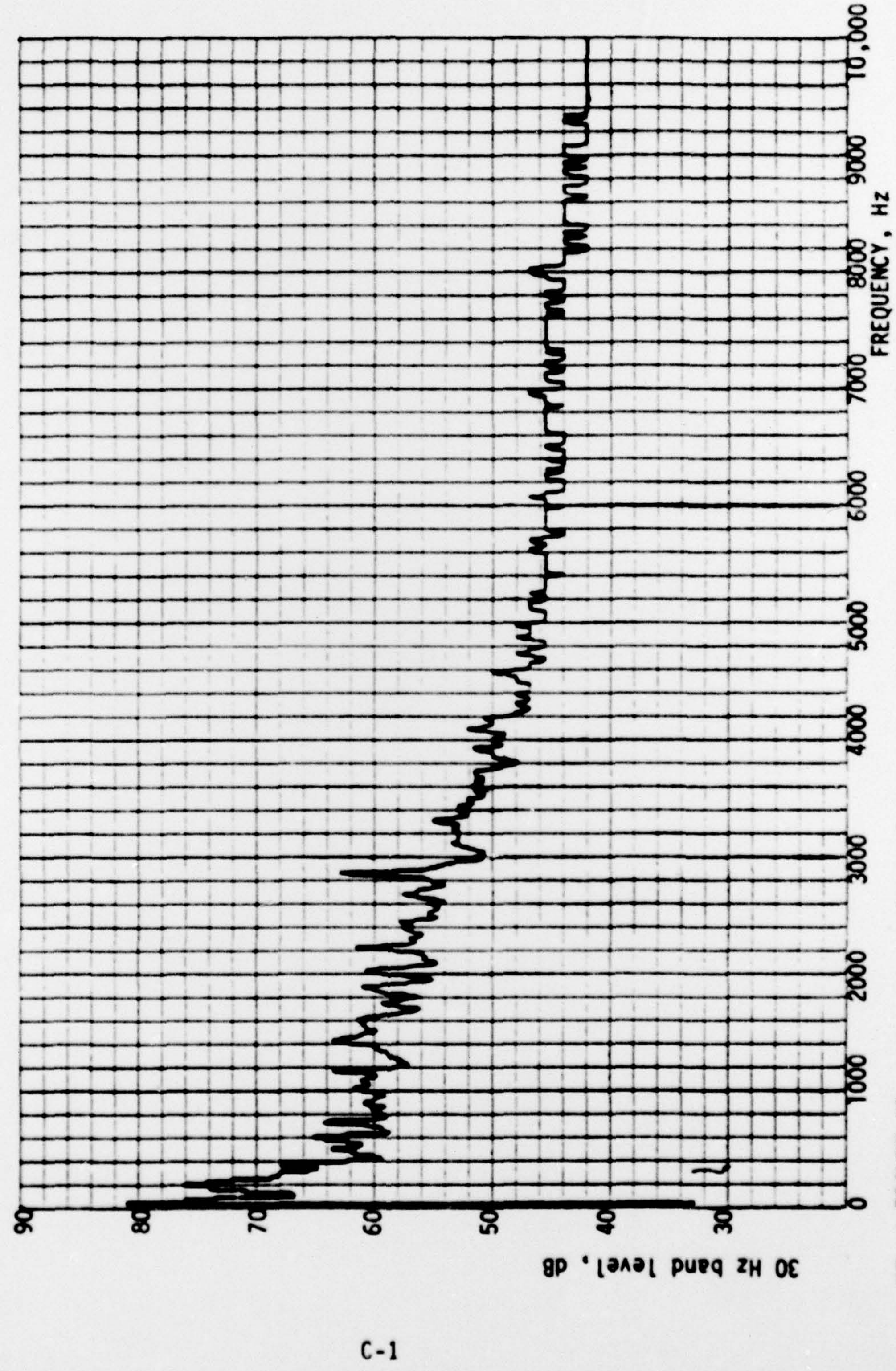


FIGURE C1. Narrowband (30 Hz) analysis of the noise in transmitter set -02 with shelter blowers and ventilation fans on, RF power off, position 1, PA doors open

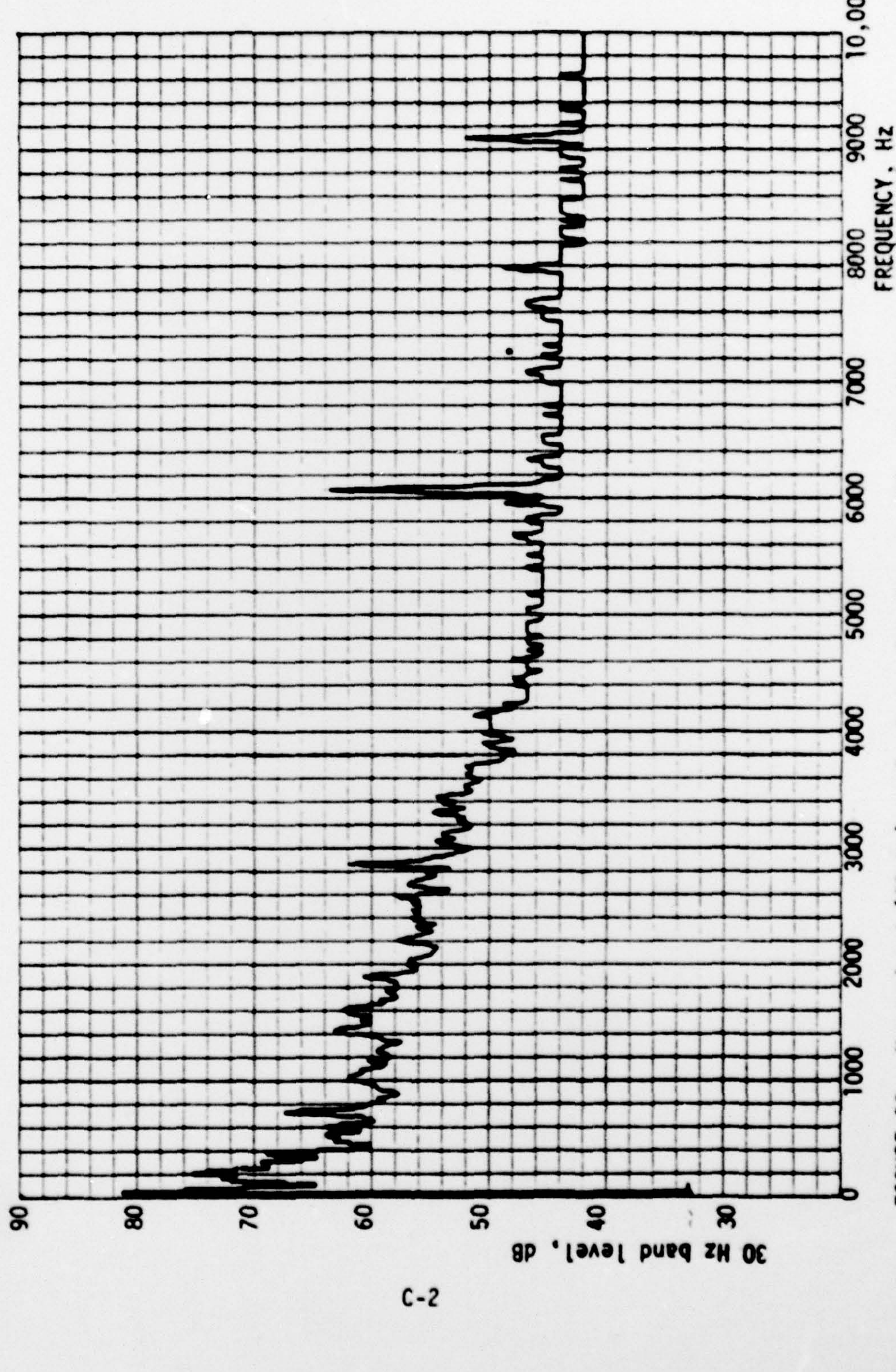


FIGURE C2. Narrowband (30 Hz) analysis, noise in set -02. Conditions same as for Figure C1 except operating at full RF power.

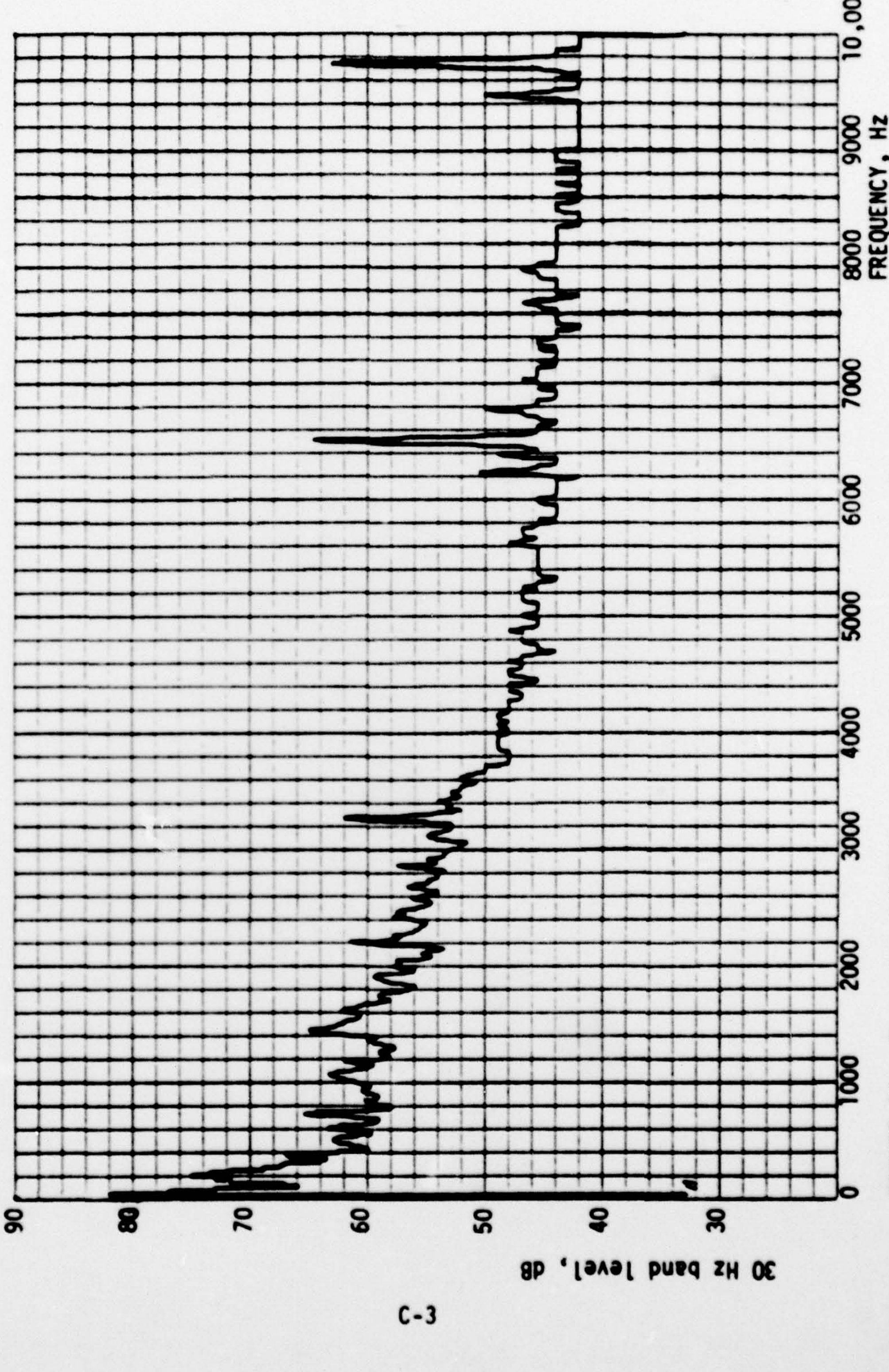


FIGURE C3. Narrowband (30 Hz) analysis, noise in set -02.
Conditions same as for Figure C2 except a few minutes later.

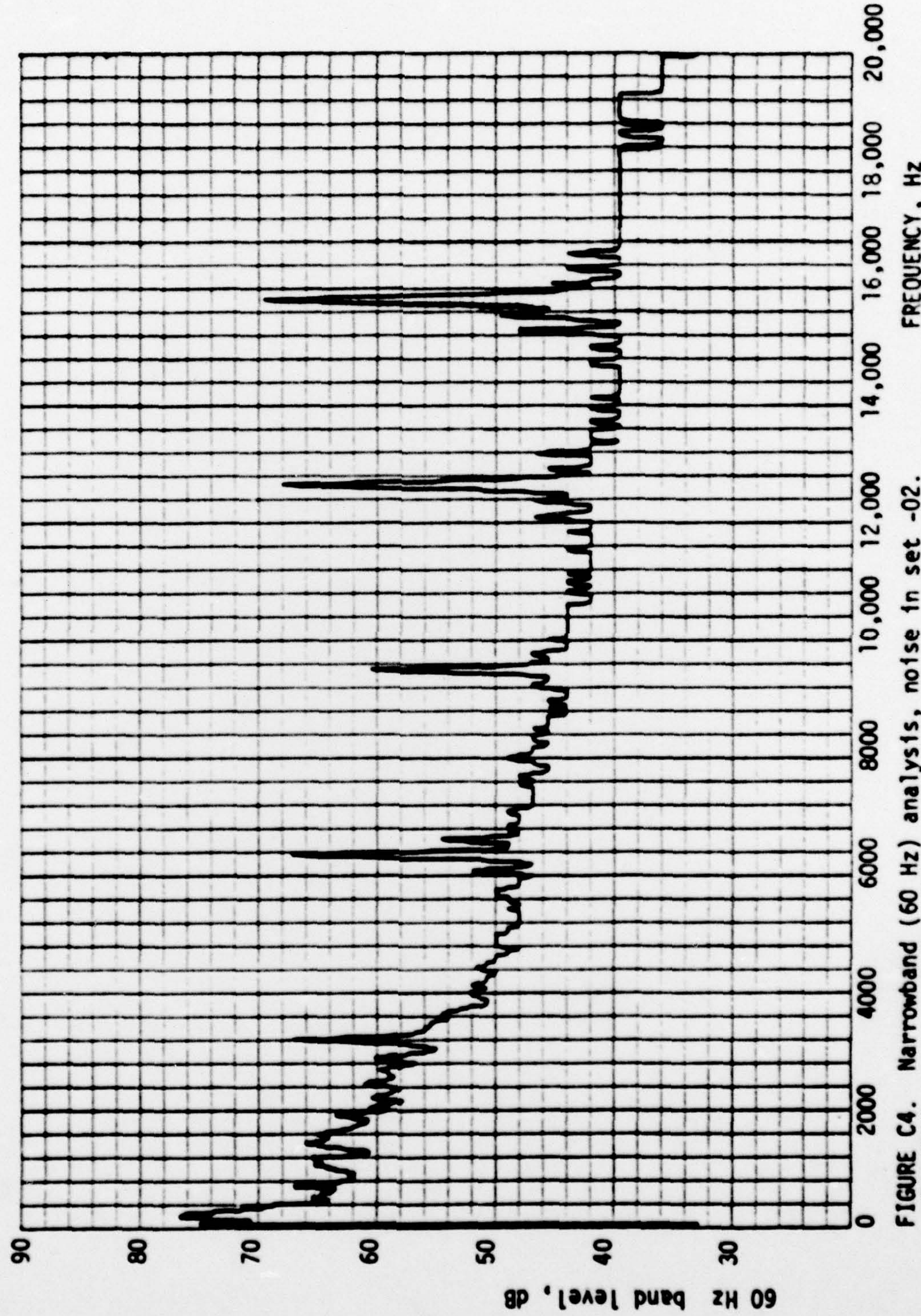


FIGURE C4. Narrowband (60 Hz) analysis, noise in set -02. Conditions same as for Figure C3 except a few seconds later.

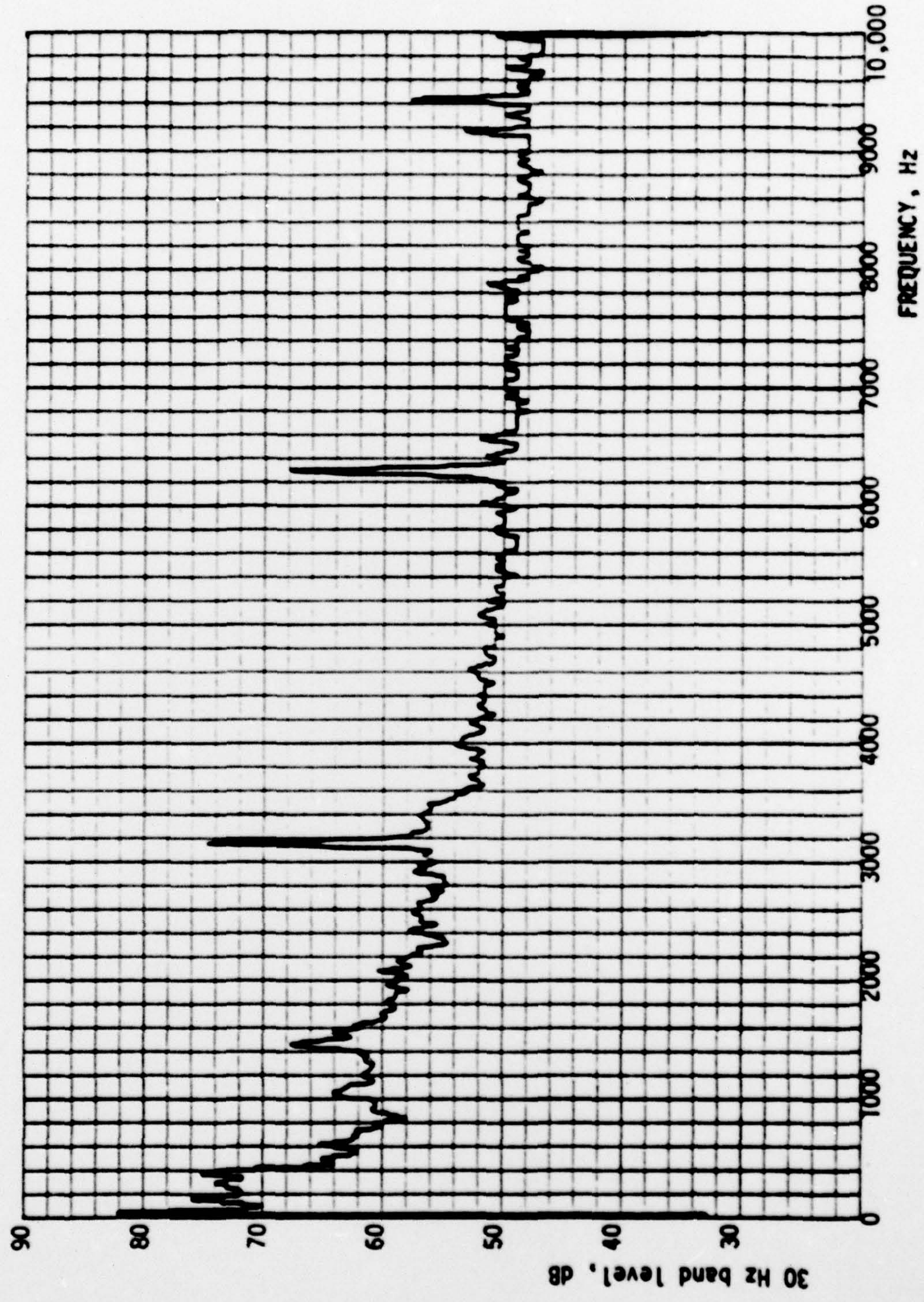


FIGURE C5. Narrowband (30 Hz) analysis of the noise in transmitter set -07 with shelter blowers and ventilation fans on, full RF power, PA doors open.

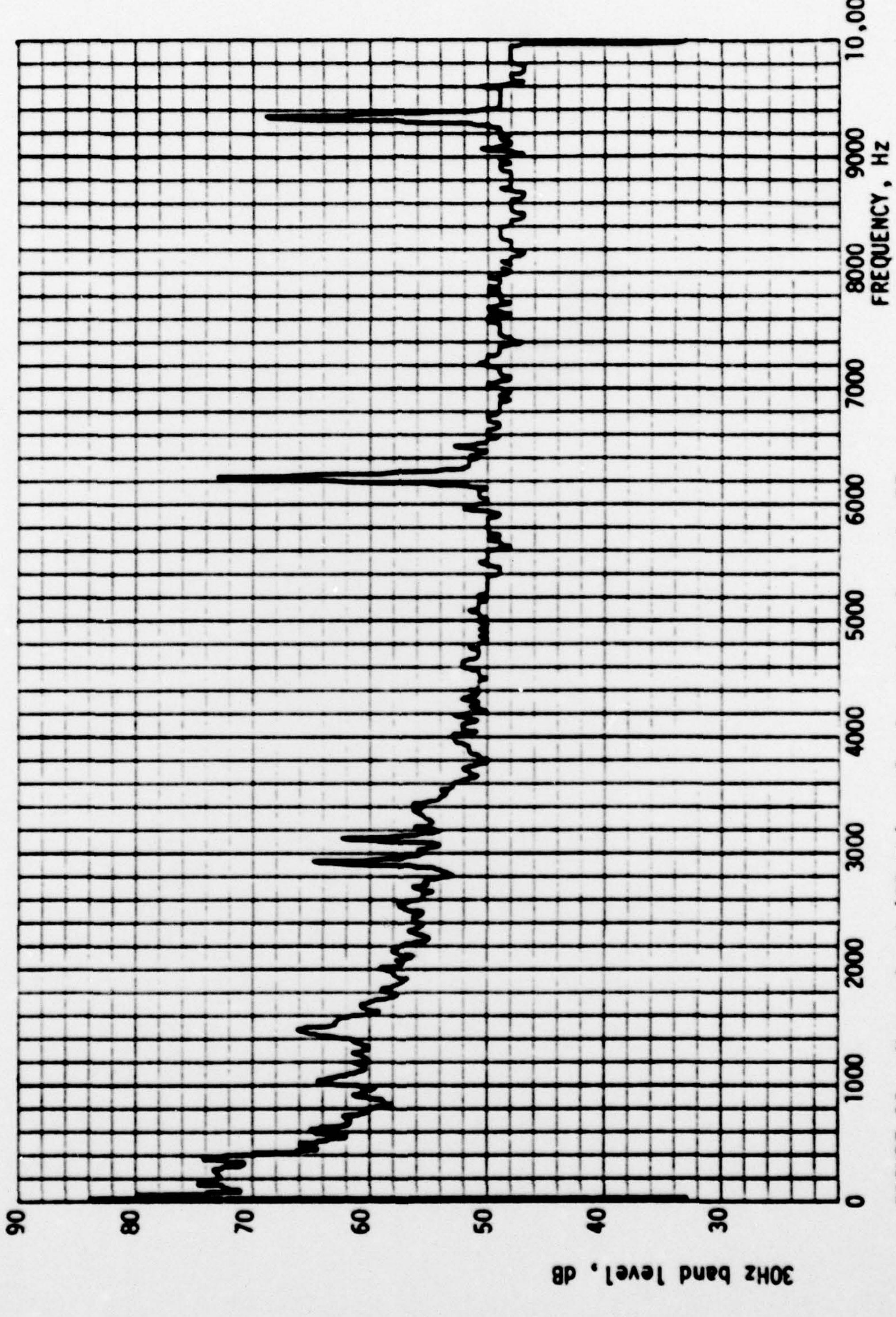


FIGURE C6. Narrowband (30 Hz) analysis, noise in set -07.
Conditions same as for Figure C5 except shelter door open wide.

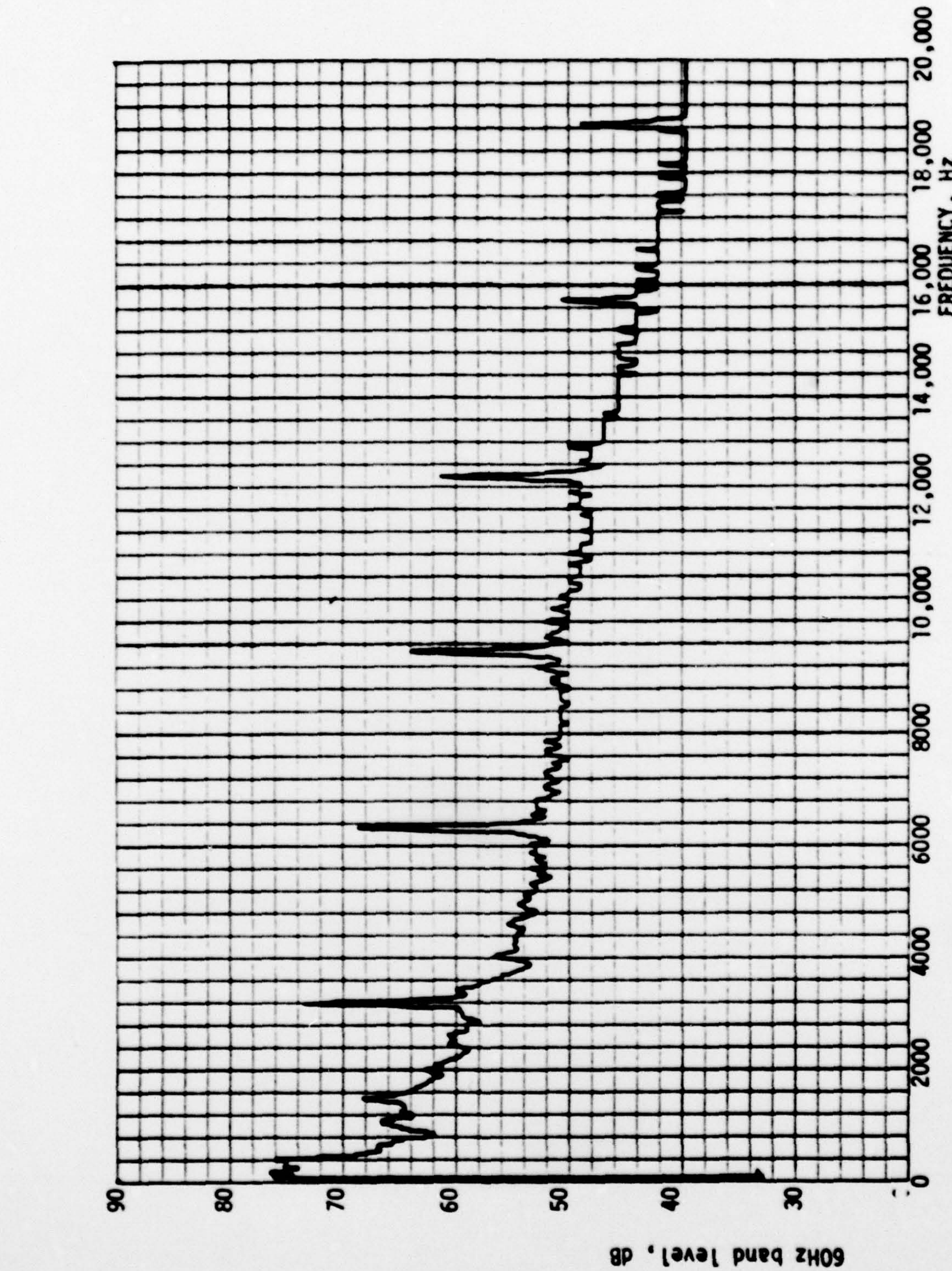


FIGURE C7. Narrowband (60 Hz) analysis, noise in set -07.
Conditions same as for Figure C5.

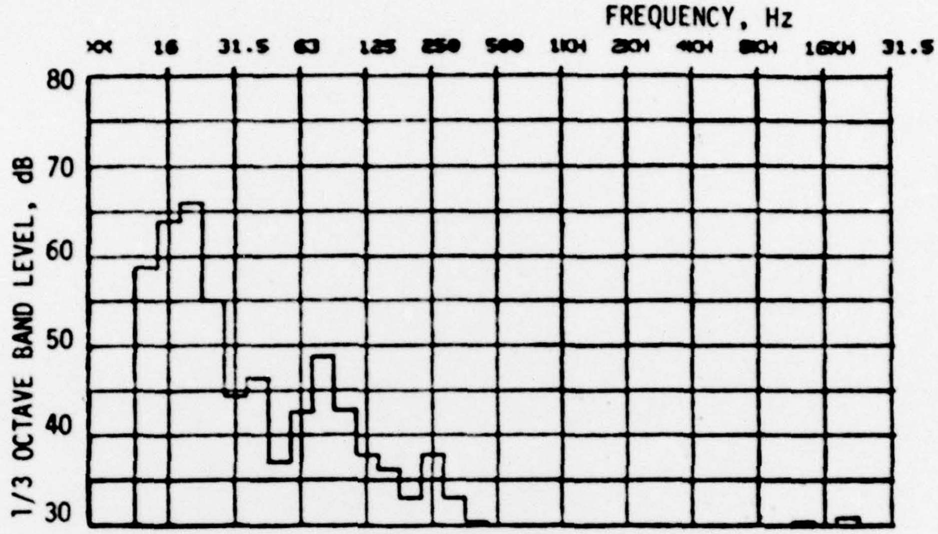


FIGURE D1. 1/3 OCTAVE BAND ANALYSIS OF THE NOISE IN TRANSMITTER SET -02 WITH ALL EQUIPMENT OFF

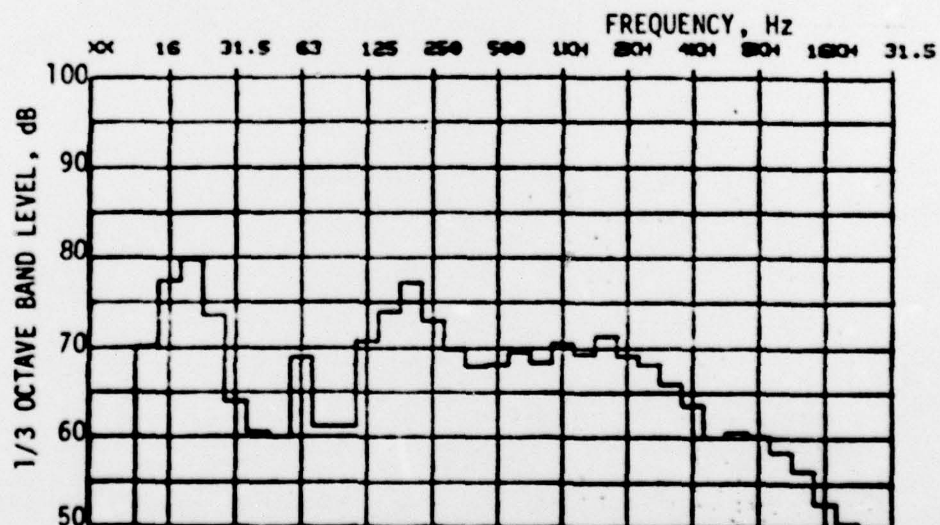


FIGURE D2. 1/3 OCTAVE BAND ANALYSIS OF THE NOISE AT POSITION 1 IN SET -02 WITH SHELTER BLOWERS AND VENTILATION FANS ON, RF POWER OFF

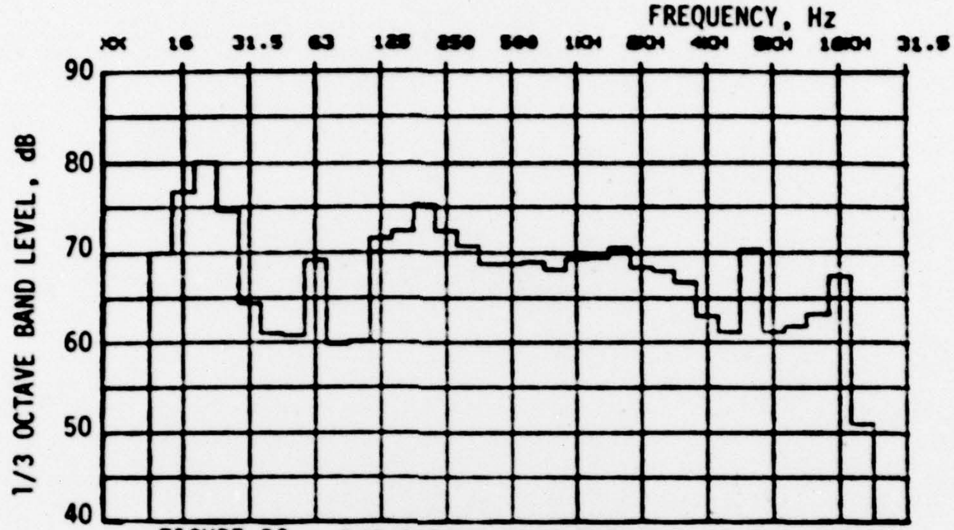


FIGURE D3. 1/3 OCTAVE BAND ANALYSIS OF THE NOISE AT POSITION 1 IN SET -02 NORMAL OPERATION WITH FULL RF POWER, JUST AFTER START

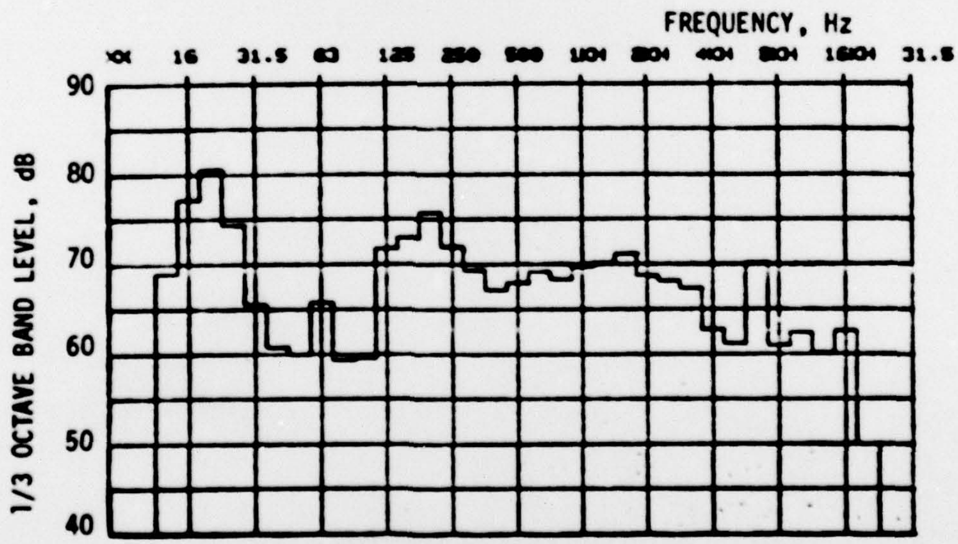


FIGURE D4. 1/3 OCTAVE BAND ANALYSIS. CONDITIONS AS IN FIGURE D3 BUT ONE MINUTE LATER

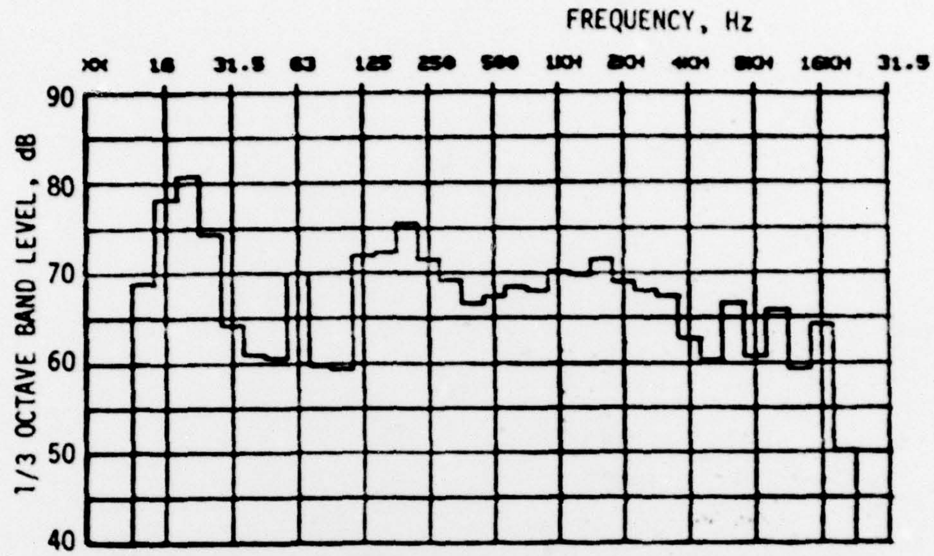


FIGURE D5. 1/3 OCTAVE BAND ANALYSIS, CONDITIONS AS IN FIGURE D3 BUT TWO MINUTES LATER

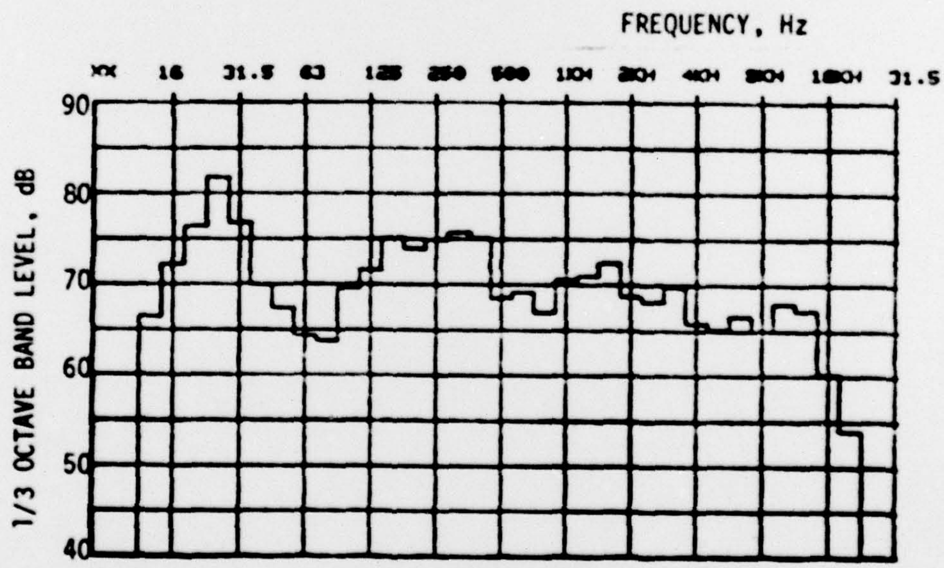


FIGURE D6. 1/3 OCTAVE BAND ANALYSIS. POSITION 2 IN SET -07, NORMAL OPERATING CONDITIONS, PA DOOR OPEN, FULL RF POWER, SHELTER DOOR OPEN

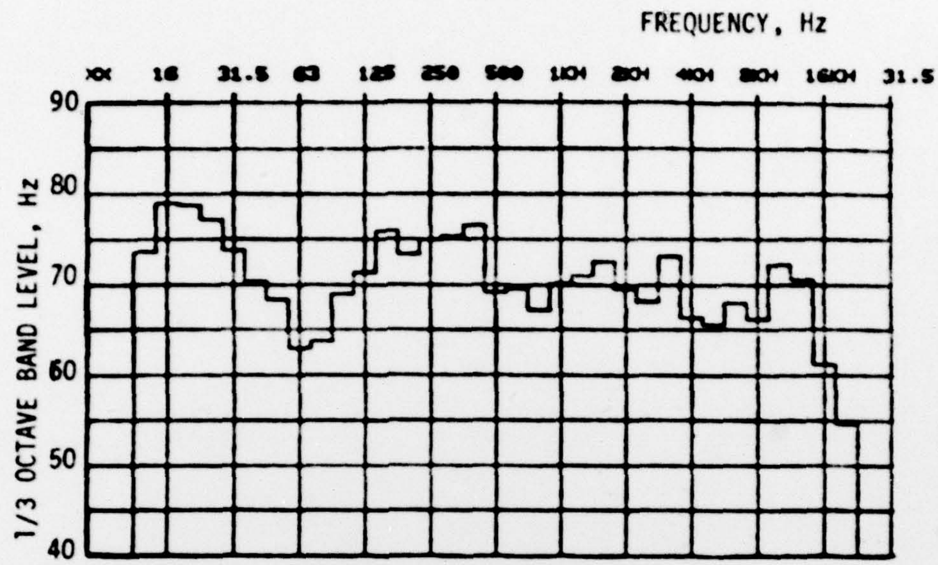


FIGURE D7. 1/3 OCTAVE BAND ANALYSIS.
CONDITIONS SAME AS FOR FIGURE D6 BUT
SHELTER DOOR CLOSED

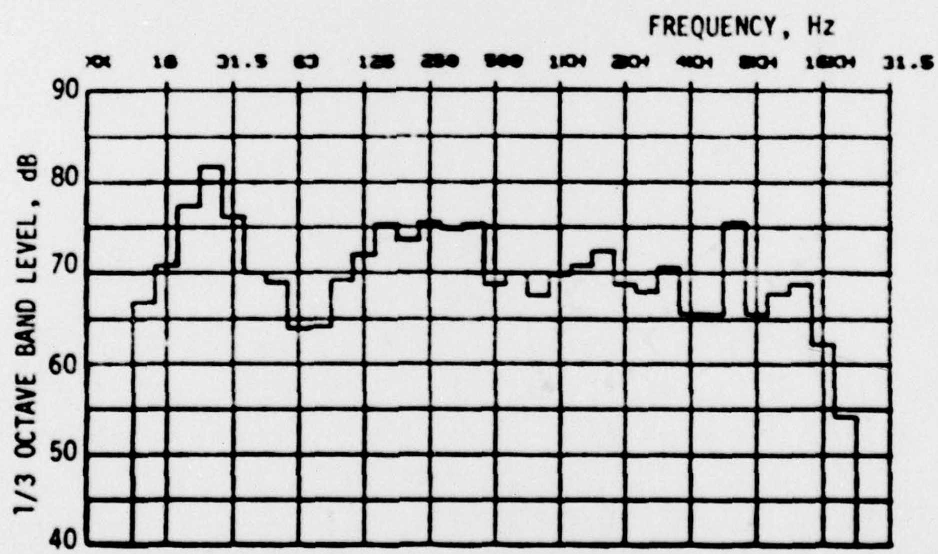


FIGURE D8. 1/3 OCTAVE BAND ANALYSIS.
CONDITIONS SAME AS FOR FIGURE D7 BUT
SOME TIME LATER